3. Description of the Study Area

The study area lies in the north-central part of Puerto Rico, at the town of Manati. The project sites are is located south of the Expressway PR-22 and at the town of the municipality of Manati (figure 1). The study area is composed mostly of urban lands.

The study area topography is steep and semi-flat lands, with the presence of some karst mountains and developed areas. A terrain elevation varies from 5 to 160 meters. The vegetal cover within the study consists of grass and scattered trees and bushes.

4. Preliminary Evaluation

During a reconnaissance visit to the study area, the contributing drainage areas of the nearby lands and its drainage areas were inspected and defined. Since the study area is located in the town of Manati, the presence of storm sewer system consisting of inlets and pipes was noticed.

Along the State Road PR-2 a 60" diameter reinforced concrete pipe drains part of the storm waters toward the west direction. An existing box culvert, located northeast of a car sales dealer drains part of the flood waters from the town of Manati into an unnamed creek which discharges into the existing storm sewer system of the State Road PR-604. From there the floodwaters flow toward the West direction and incorporate into a existing rectangular concrete canal which drains beneath exiting houses located along the State Road PR-685. Finally the floodwaters discharge into open lands located West of State Road PR-685.

The drainage areas topography, vegetal cover, land use, drainage pattern (for low and high stage) throughout the project site and its vicinity were documented.

The physical characteristics of the intermittent unnamed creek and the rectangular concrete canal, such as, the streambed material composition, channel geometry, channel slope, vegetation, reach alignment, and overbanks were observed to determine the roughness coefficients that will be considered for the hydraulic models. The main channel is covered mainly by grass, with some small bushes along the banks. Vegetation along the overbanks consists mainly of small to large bushes, dense in some areas, and some small to large trees. According to the Flood Insurance Rate Map, the project is not located in f100d area (Zone X), figure 2.

5.3 Basin Parameters: Curve Number, Lag Time, arid Time of Concentration

The hydrologic simulation requires the determination of the following basin parameters: curve number, time of concentration, and lag time. The lag time computation requires determining the average watershed slope, the reach length, and the curve number.

The curve number represents the potential of a watershed to generate runoff. It is a function of the soil type, hydrologic soil group, vegetal cover, land use, and the antecedent moisture condition. The soil types within the basins were determined based on the Soil Survey of the Arecibo Area of Northern Puerto Rico (Soil Conservation Service, 1982). The infiltration rates of soils vary widely and are affected by subsurface permeability as well as surface intake rates. The hydrologic soil groups defined by the Soil Conservation Service are: A, low runoff potential and high infiltration rate; B, moderate infiltration rate; C, low infiltration rate; and D, high runoff potential. Table 2 shows the soil type and the hydrologic soil group for the soils contained within the study basins. Figure 4 shows the soil types within the study basins.

Table 2. Soil types and soilgroups identified in the study basins

Soil	Description	Soil
AnB	Almirante Clay	B
ByB	Bayamón Clay	B
Cn	Coloso Silty Clay	B
EcB	Espinosa C/ay	B
Ps	Pits, Gravel	D
RtF	Rock Outcrop- Tanama Complex	D
TaG2	Tanama Glay, 5-12% slope	D
TaD2	Tanama Clay, 10-20% slope	D
To	Toa Silty Clay Loam	B
Ur	Urban Land	D

As seen from table 2, soil group consists of hydrologic soil group B (moderate infiltration rates) and D (high runoff potential). The vegetal cover of these basins consists of concrete and asphalt for the urban areas, forest (in the basin headwaters and in hilly areas), brush, weed, and grass (predominantly).

The time of concentration is determined by the Soil Conservation Service methodology. The time of concentration is a function of the lag time (L) of the basin. The lag time is computed by the following formula:

1 0.8 (S+1)0.7

L = ----------------------

1900 Y 0 .5

Table 4 - Precipitation Frequency Estimates for the 24 hour duration 100 year recurrence.

Subbasin ID	Precipitation (millimeters)	Precipitation (inches)
B-1	318.30	12.53
B-2	324.40	12.77
B-3	318.30	12.53
B-4	324.40	12.77
B-5	313.20	12.33
B-6	313.20	12.33
B-7	313.20	12.33
B-8	303.80	11.96

5.5 100-year Flood Discharges

The HEC-HMS computer model was used to determine the 100-year direct runoff hydrograph for the 24-hour storm duration. Direct runoff hydrographs were estimated at each subbasin outlet. The basin schematic for existing conditions is shown in Figure 5. Hydrographs were calculated for each subbasin and were combined at their corresponding junction and routed throughout the corresponding reaches and combined with the arriving hydrographs until its final discharge point (outlet). A summary of the 100-year flood discharges obtained from the HEC-HMS simulations for existing and proposed conditions are shown in Table 5.

Table 5. Summary of 100-year peak flood discharges

	EXISTING CONDITIONS		PROPOSED CONDITIONS	
Subbasin	Peak Discharge (m3/s)	Peak Discharge (ft3/s)	Peak Discharge (m3/s)	Peak Discharge (ft3/s)
1	14.79	522.23	14.79	522.23
2	17.44	615.80	17.44	615.80
3	4.58	161.72	4.58	161.72
4	17.60	621.46	17.60	621.46
5	1.64	57.91	1.64	57.91
6	7.96	281.07	7.96	281.07
7	10.11	356.98	10.11	356.98
8	--	--	4.16	146.89

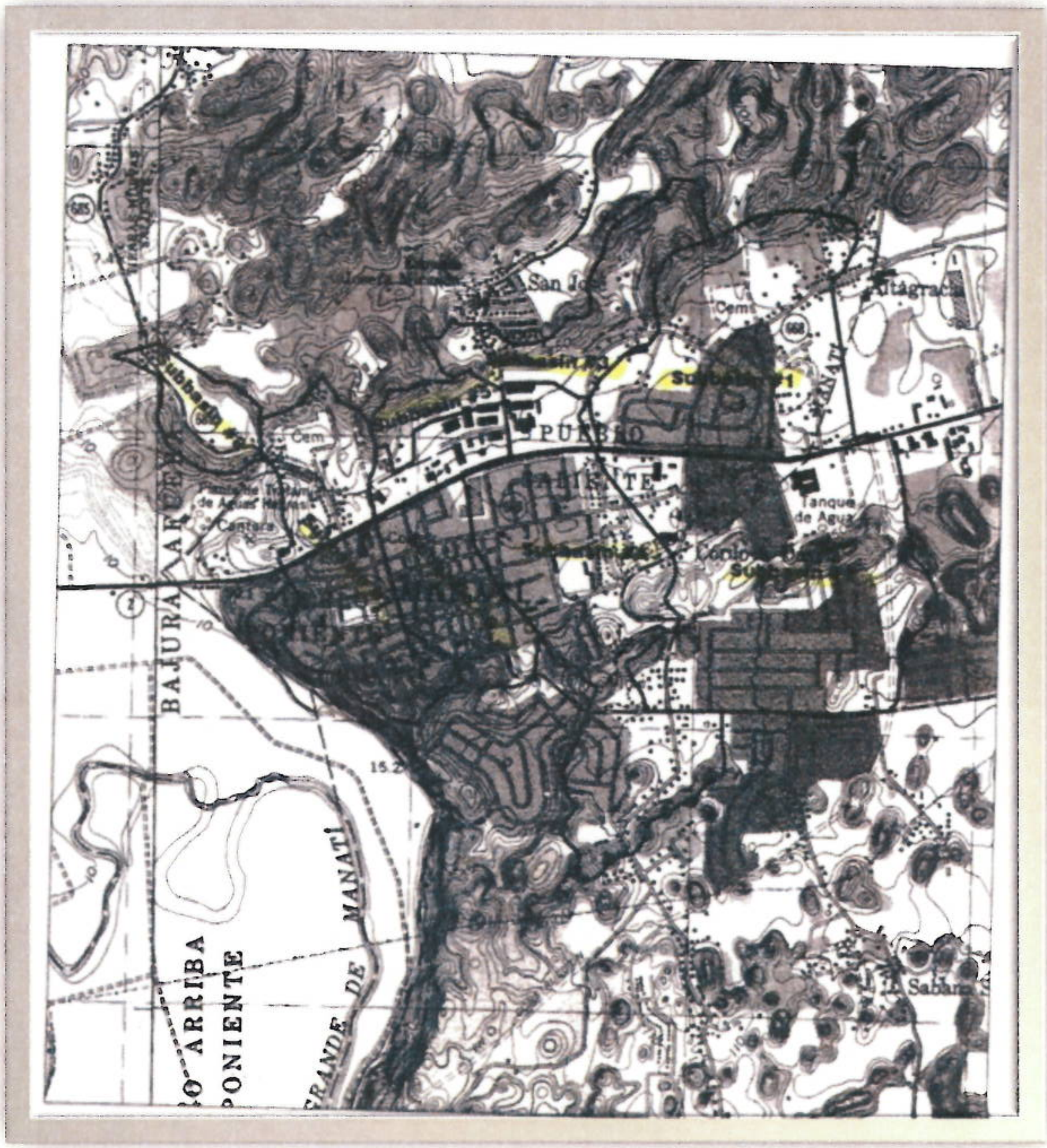
As seen from Table 5, the 100-year flood peak discharges for existing conditions fluctuates from 1.64 to 17.60 m3/s. Figures 6 to 16 show the computed 100-yearflood hydrograph at each subbasin outlet and junction.

The basin schematic for proposed conditions is shown in Figure 17. Hydrographs were calculated for each subbasin and were combined at their corresponding junction and routed throughout the corresponding reaches and combined with the arriving hydrographs at its final discharge point (outlet). For proposed conditions, Subbasin 8 was included in the hydrologic simulation because at the discharge point of the system, the runoff generated by Subbasin 8 should be taken in consideration. As seen from Table 5, the 100-year flood peak discharges for Subbasin 8 resulted in 4.16 m3/s. Figures 18-20 shows the computed 100-year flood hydrograph at Junction 4, Subbasin 8 and Junction 5, respectively.

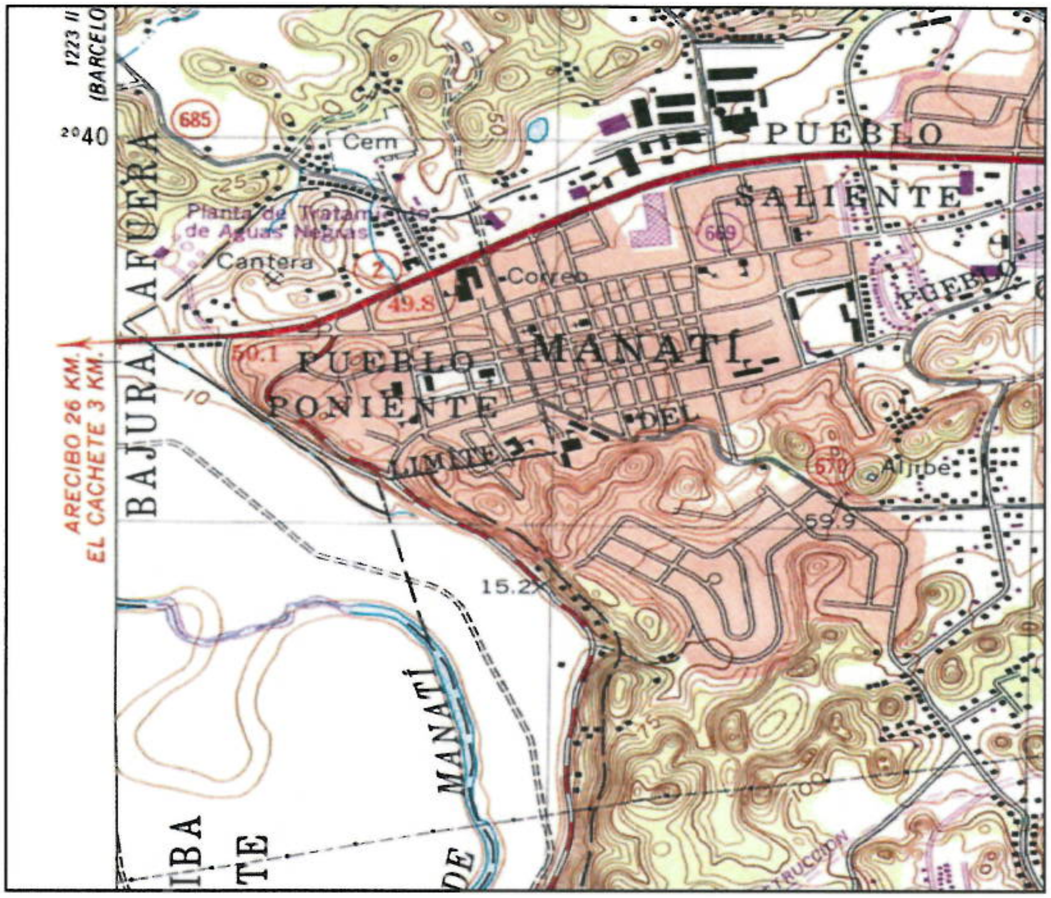
6. Conclusion and Recommendations

The 100-year flood hydrograph peak discharge for existing and proposed conditions fluctuates from 1.64 to 17.60 m3/s. The computed peak discharges will be used to conduct the hydraulic analysis in order to determine the adequate hydraulic works to manage the computed peak discharges.

Figure 1 - Study Area, Map of Manati Topographic



Map of Manati Topographic



Fuente: US Geological Survey, 1969 y editado en el 1982.

FIGURE 2 - MAP OF AREAS SUSCEPTIBLE TO FLOODING

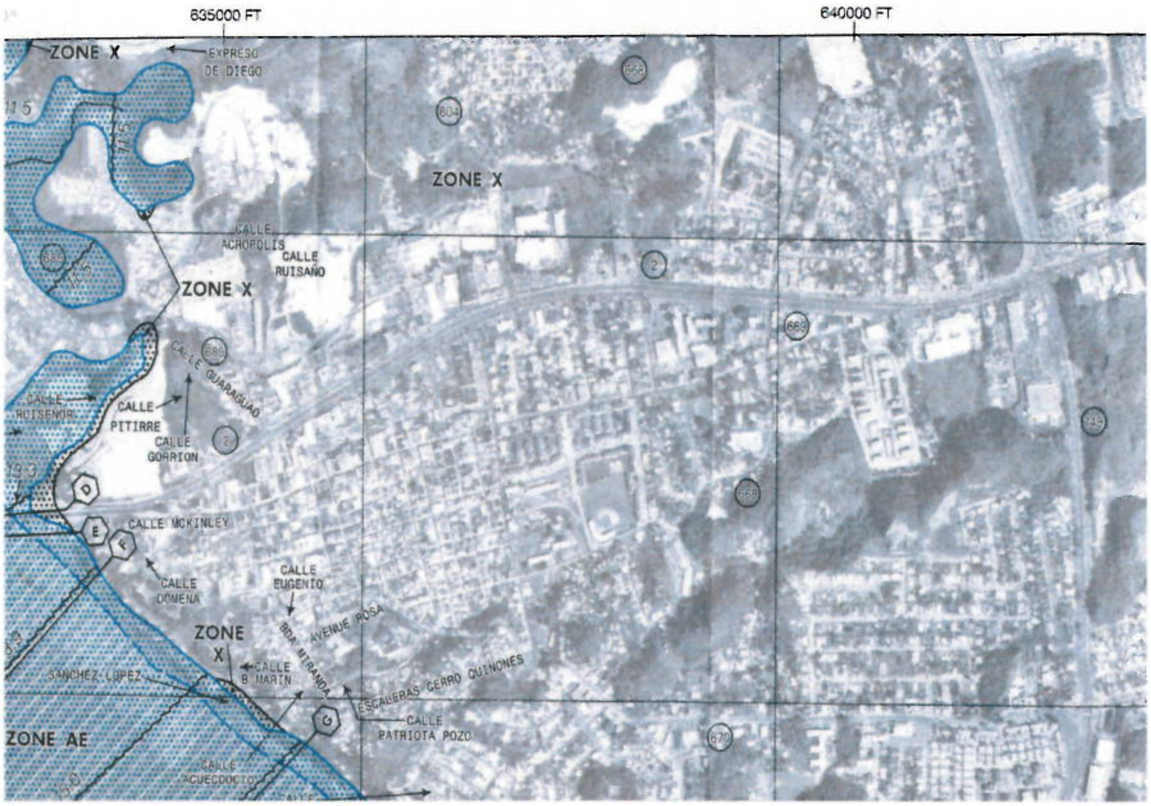
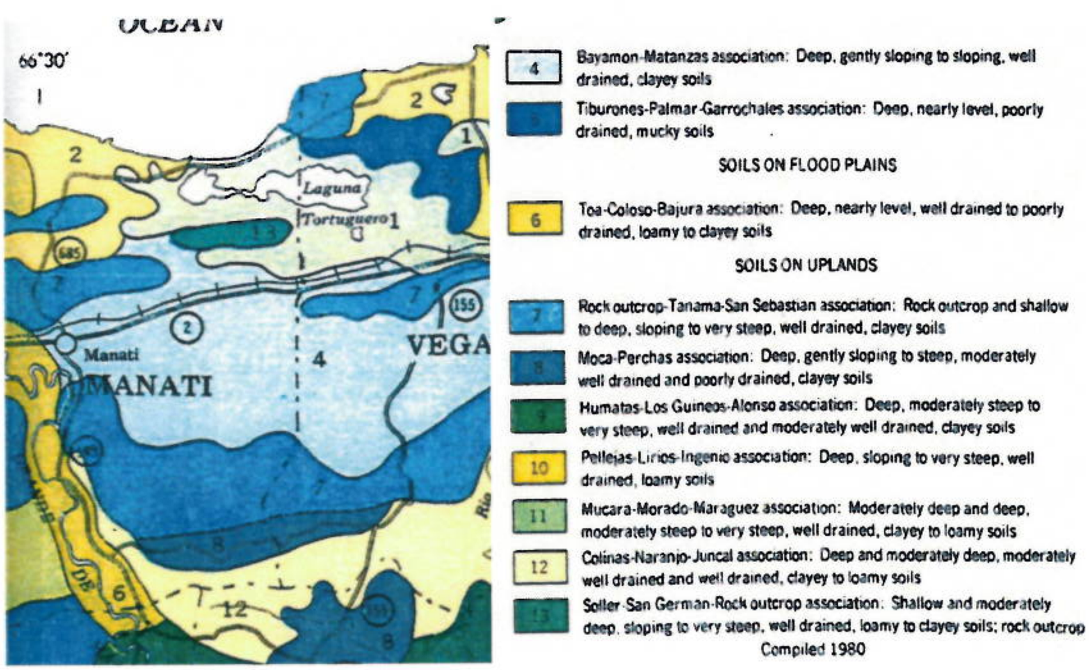


FIGURE 4. SOIL MAPS

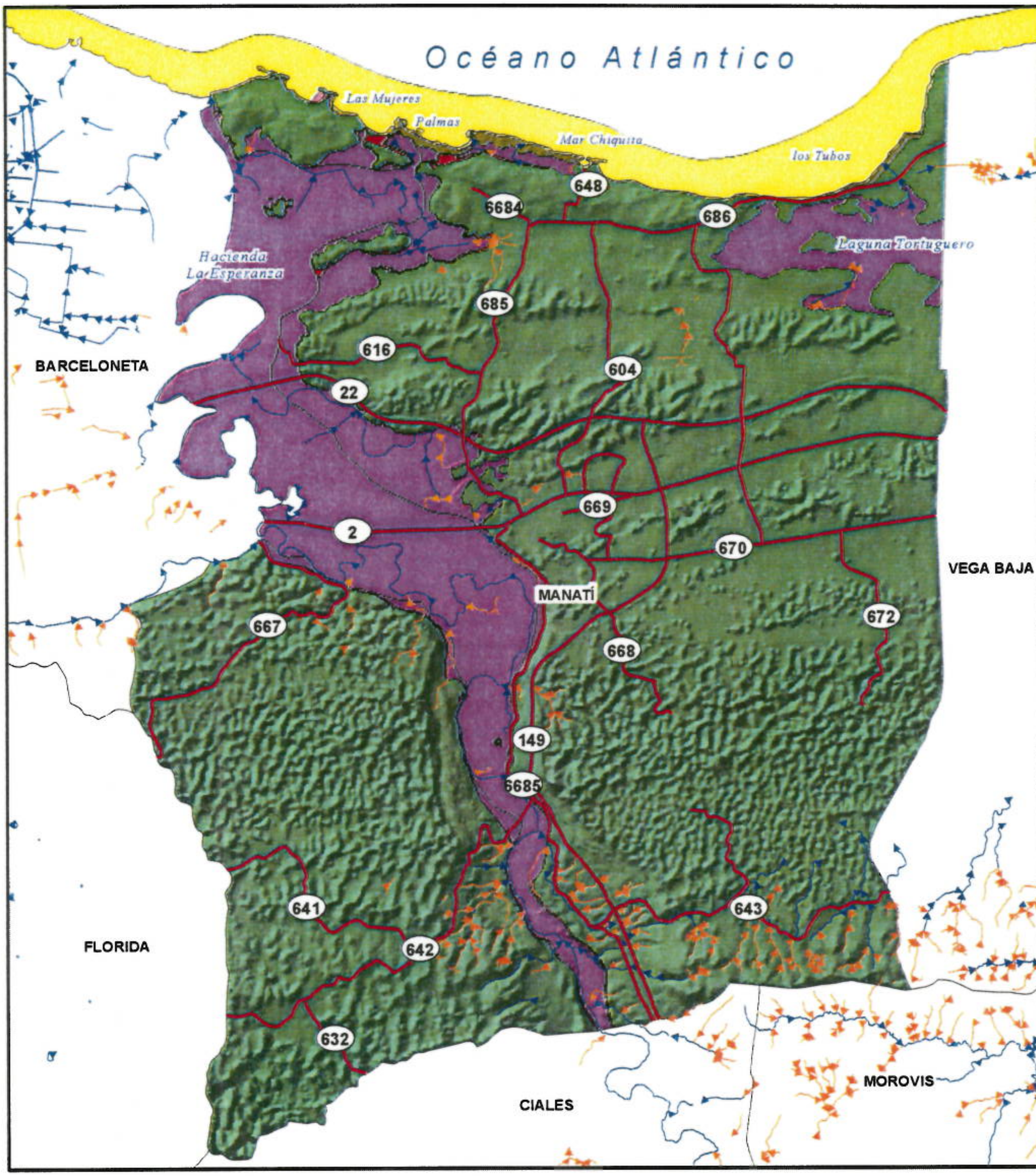


Tipo de suelo en el CUT: Núm. (4) Bayamón- Matanzas association: deep, gentil sloping to sloping, well drained, clayey soils.

Anejo 4

Mapa de Flujograma Hidrográfico y su Zona de Inundabilidad.

Flujograma Hidrográfico y su Zona de Inundabilidad



LEYENDA

Flujograma Hidrográfico

Patrón Hidrográfico
- Inconstante
- Constante
- Limite Municipal Manatí
- Mar, Lagos, Lagunas, Rios y Quebradas
- Municipios Colindantes
- Carreteras

Zona de Inundabilidad
- 0.2 PCT Riesgo Anual de Ocurrir una Inundación
- A
- AE
- AH
- AO
- D
- VE
- X

N

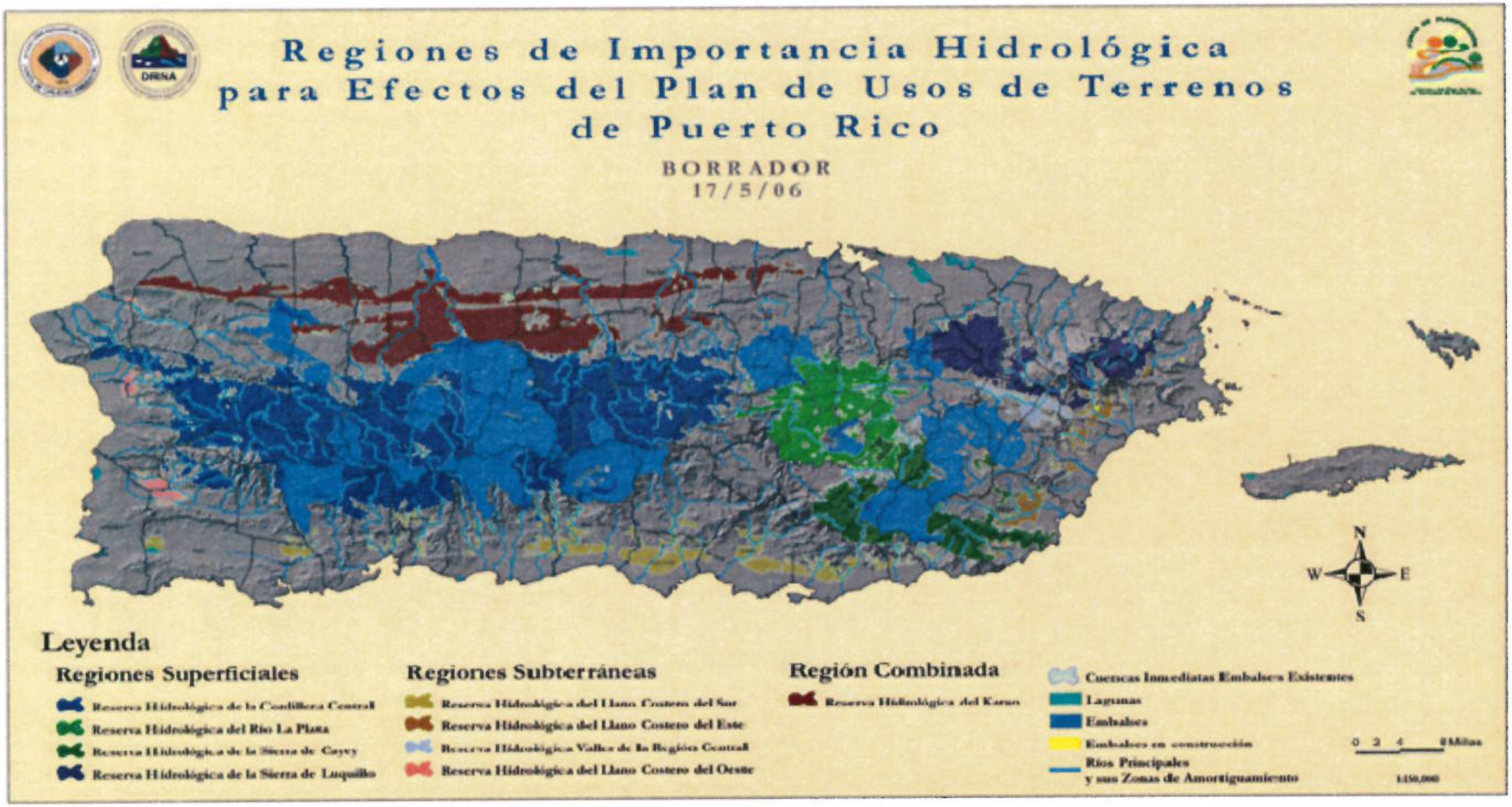
1:82,000

480 240 0 480 960
Metros

Fuente de información suministrada por: (DRNA) Departamento de Recursos Naturales, (JP) Junta de Planificación, (ACT) Autoridad de Carreteras, (USGS) United States Geological Survey, (OGP) Oficina de Gerencia y Presupuesto, (CRIM) Centro de Recaudos e Ingresos Municipales.

Cartografía Elaborada por: División SIG, Oficina de Planificación Estratégica y Ordenación Territorial, Municipio Autónomo de Manatí

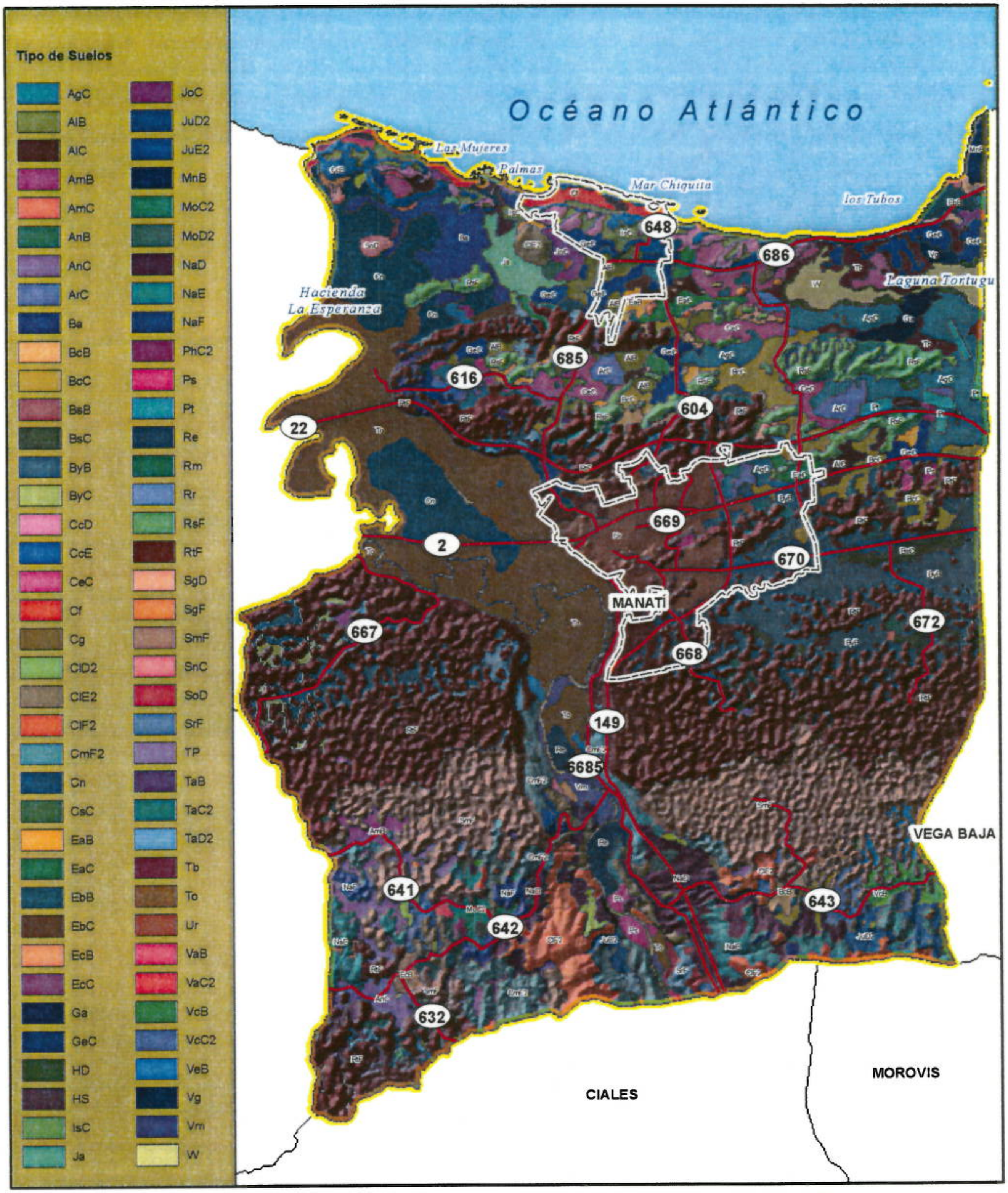
El Geodato del (FIRMS) Flood Insuranse Rate Map es suministrado por Junta de Planicafioion y FEMA.


Regiones de Importancia Hidrológica
para Efectos del Plan de Usos de Terrenos
de Puerto Rico
BORRADOR
17/5/06
N
W
E
S
Leyenda
Regiones Superficiales
Reserva Hidrológica de la Cordillera Central
Reserva Hidrológica del Río La Plata
Reserva Hidrológica de la Sierra de Cayey
Reserva Hidrológica de la Sierra de Luquillo
Regiones Subterráneas
Reserva Hidrológica del Llano Costero del Sur
Reserva Hidrológica del Llano Costero del Este
Reserva Hidrológica Valles de la Región Central
Reserva Hidrológica del Llano Costero del Oeste
Región Combinada
Reserva Hidrológica del Karso
Cuencas Inmediatas Embalses Existentes
Lagunas
Embalses
Embalses en construcción
Ríos Principales
y sus Zonas de Amortiguamiento
0 2 4 8 Millas

Anejo 5

Mapas de Tipo de Suelo y su Área Urbana

Tipo de Suelos y su Área Urbana



LEYENDA

Área Urbana

Limite Municipal Manatí

Mar, Lagos, Lagunas, Ríos y Quebradas

Municipios Colindantes

Carreteras

1:86,000

720 360 0 720 1,440

Metros

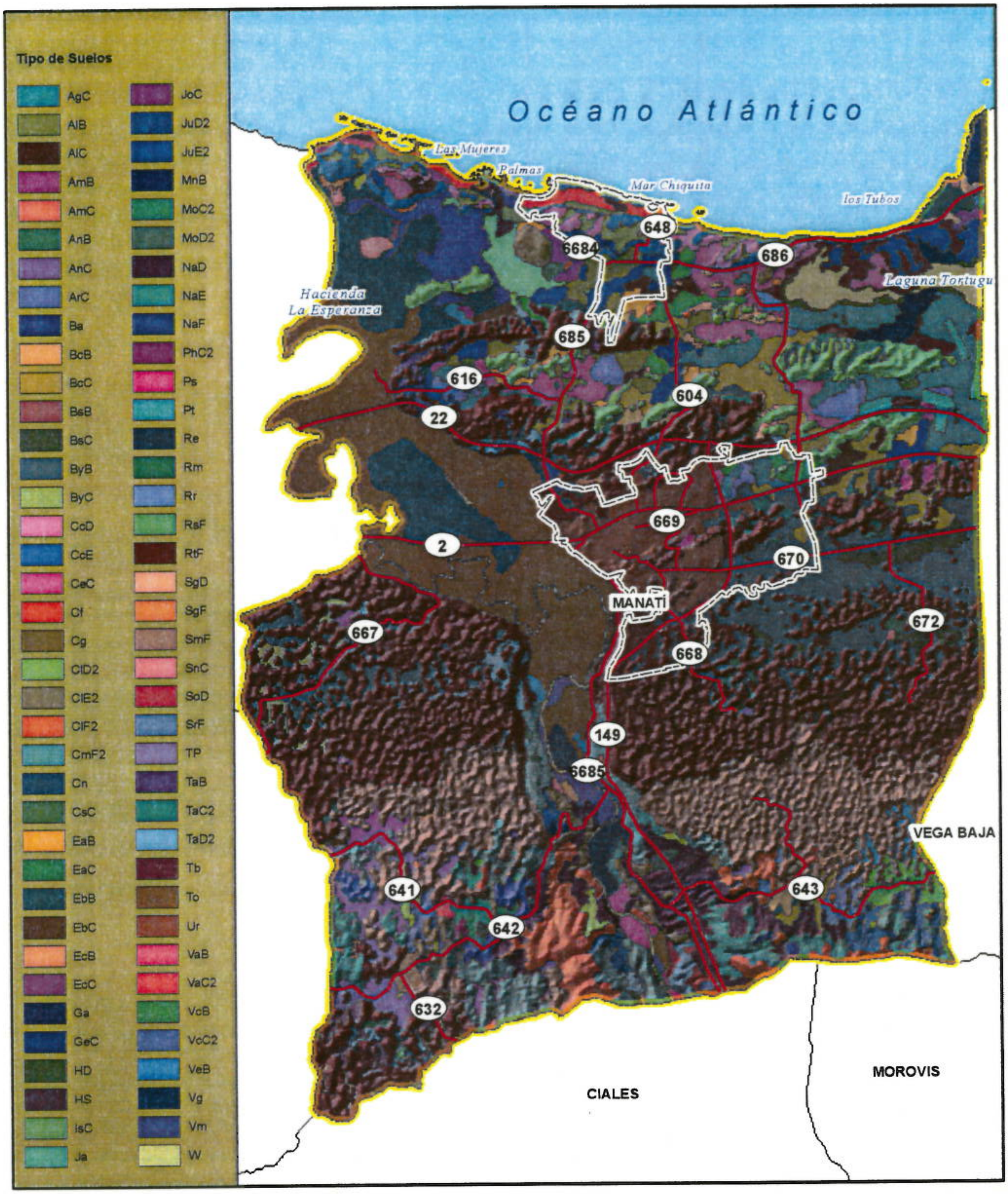
N

Fuente de información suministrada por: (DRNA) Departamento de Recursos Naturales, (JP) Junta de Planificación, (ACT) Autoridad de Carreteras, (USGS) United States Geological Survey, (OGP) Oficina de Gerencia y Presupuesto, (CRIM) Centro de Recaudos e Ingresos Municipales.

Cartografía Elaborada por: División SIG, Oficina de Planificacion Estratégica y Ordenación Territorial, Municipio Autónomo de Manatí

El Geodato del Tipo de Suelos fue por referencia (USGS) United States Geological Survey y adquirido por (NRCS) Natural Resources Conservation Service de la (USDA) United States Department of Agriculture

Tipo de Suelos y su Área Urbana



LEYENDA

Área Urbana

Límite Municipal Manatí

Mar, Lagos, Lagunas, Ríos y Quebradas

Municipios Colindantes

Carreteras

N

1:86,000

720 360 0 720 1,440

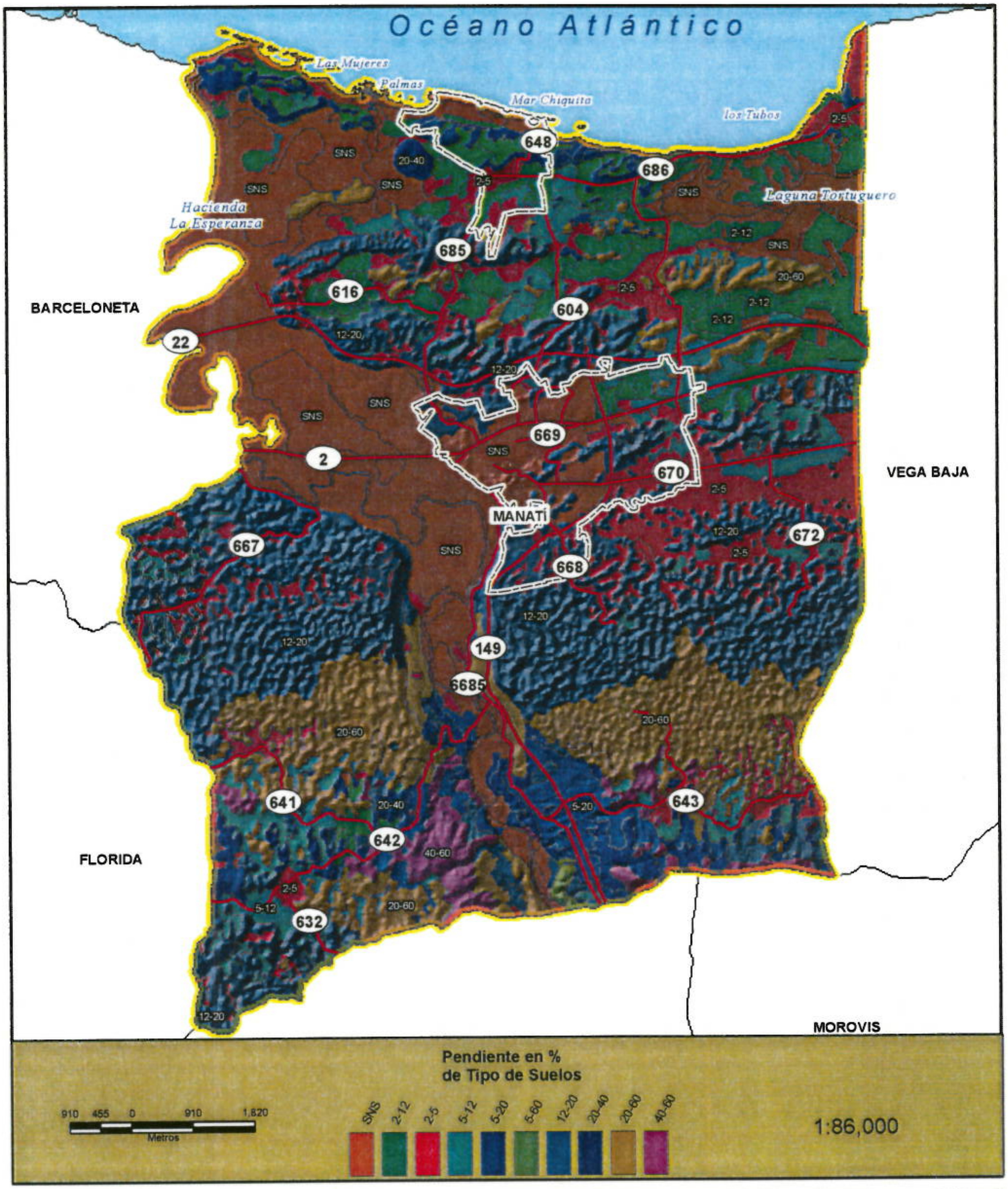
Metros

Fuente de información suministrada por: (DRNA) Departamento de Recursos Naturales, (JP) Junta de Planificación, (ACT) Autoridad de Carreteras, (USGS) United States Geological Survey, (OGP) Oficina de Gerencia y Presupuesto, (CRIM) Centro de Recaudos e Ingresos Municipales.

Cartografía Elaborada por: División SIG, Oficina de Planificación Estratégica y Ordenación Territorial, Municipio Autónomo de Manatí

El Geodato del Tipo de Suelos fue por referencia (USGS) United States Geological Survey y adquirido por (NRCS) Natural Resources Conservation Service de la (USDA) United States Department of Agriculture

Pendiente del Tipo de Suelos y su Área Urbana



LEYENDA

- Área Urbana
- Limite Municipal Manatí
- Mar, Lagos, Lagunas, Ríos y Quebradas
- Municipios Colindantes
- Carreteras

N

Fuente de información suministrada por: (DRNA) Departamento de Recursos Naturales, (JP) Junta de Planificación, (ACT) Autoridad de Carreteras, (USGS) United States Geological Survey, (OGP) Oficina de Gerencia y Presupuesto, (CRIM) Centro de Recaudos e Ingresos Municipales.

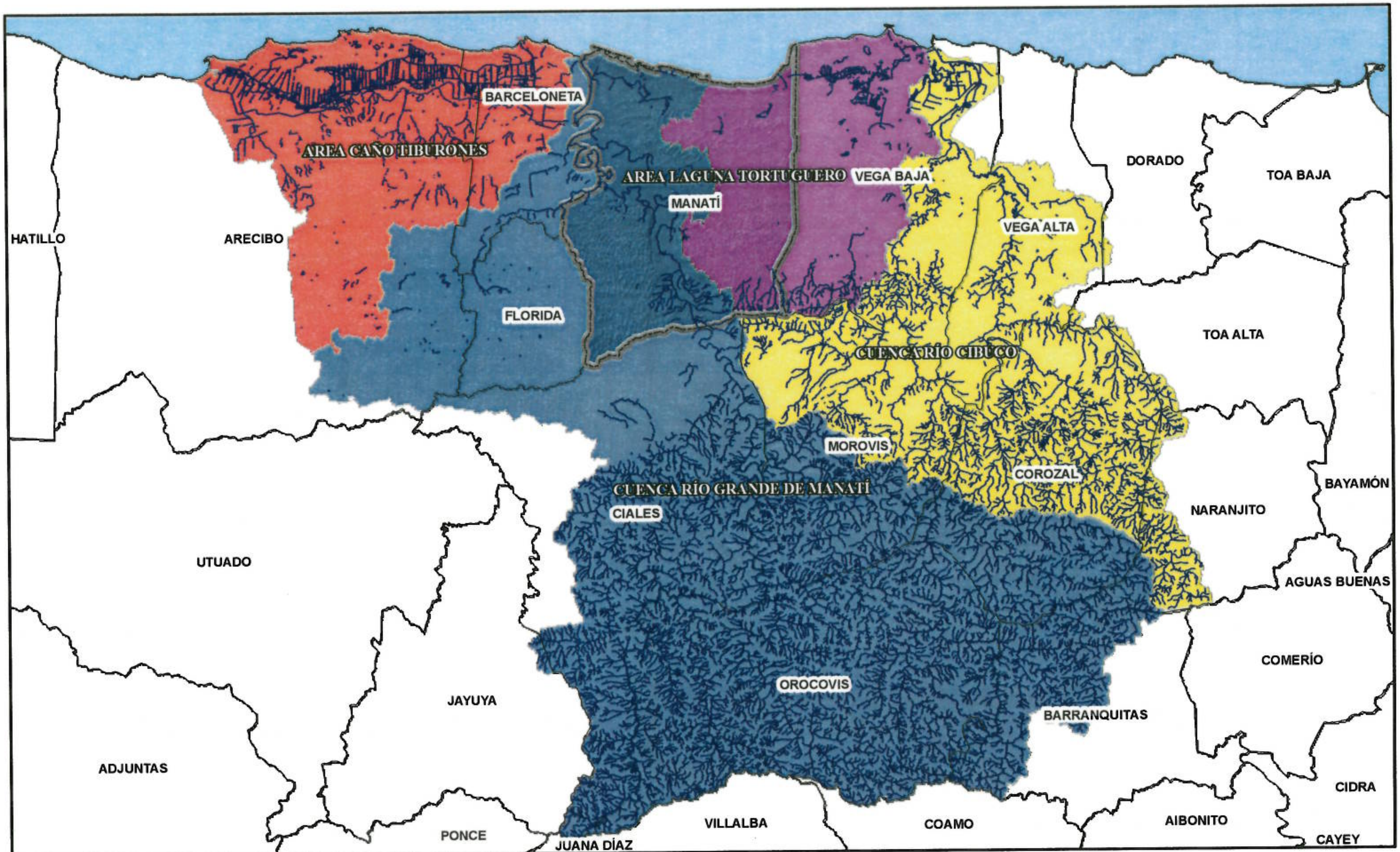
Cartografía Elaborada por: División SIG, Oficina de Planificación Estratégica y Ordenación Territorial, Municipio Autónomo de Manatí

El Geodato del Tipo de Suelos fue por referencia (USGS) United States Geological Survey y adquirido por (NRCS) Natural Resources Conservation Service de la (USDA) United States Department of Agriculture

Anejo 6

Mapa Sobre la Delimitación de la Cuenca en la Región Norte Central

Delimitación de Cuencas en la Región del Municipio de Manatí



Leyenda

- Hidrografía de la Cuenca del Río Grande de Manatí
- Límite Municipal Manatía
- Límites Municipales

Delimitación de Cuencas

- Area Caño Tiburones
- Area Laguna Tortuguero
- Cuenca Río Cibuco
- Cuenca Río Grande de Manatí

1:247,000

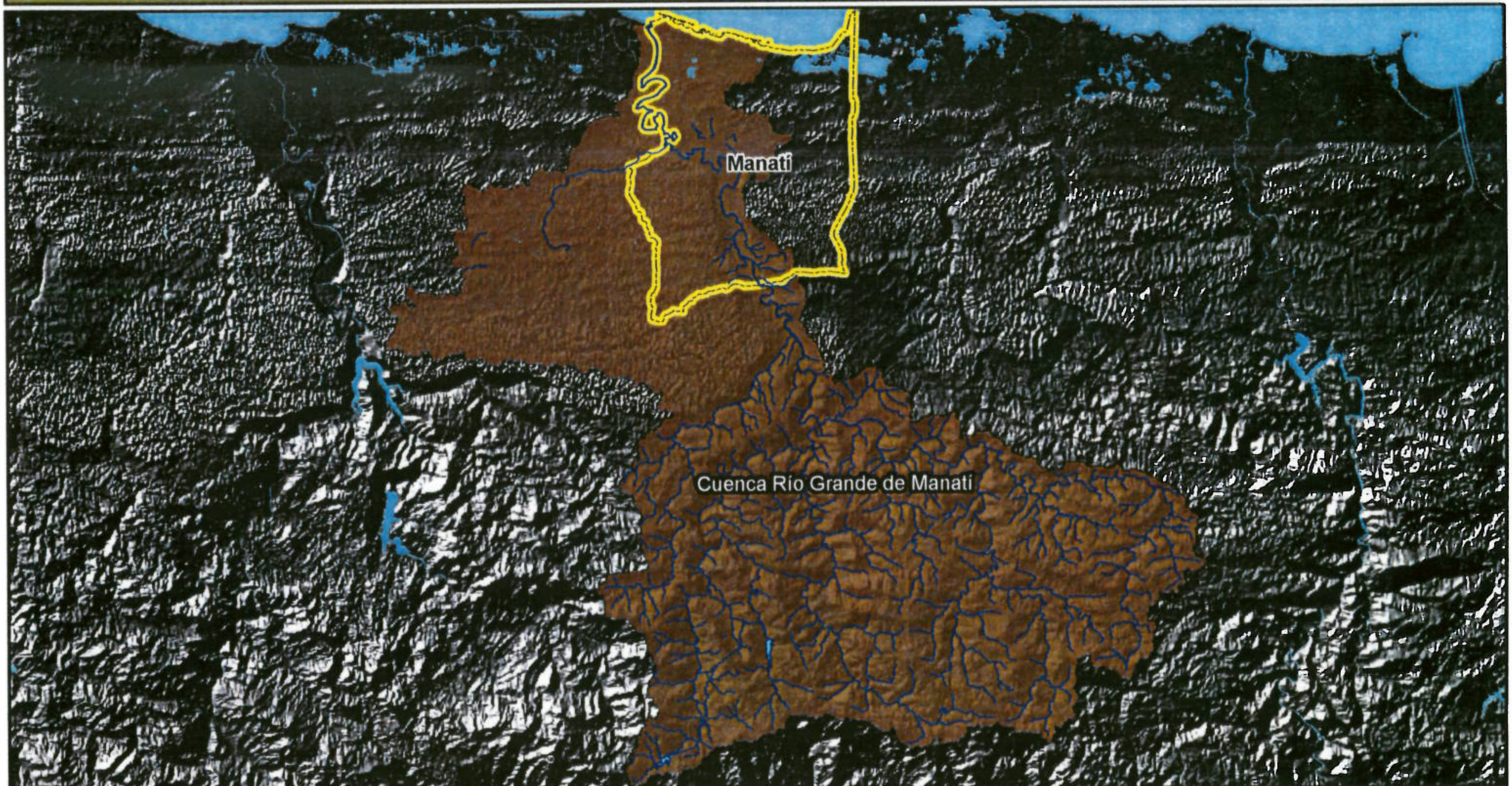
Fuente de información suministrada por: (DRNA) Departamento de Recursos Naturales, (JP) Junta de Planificación, (ACT) Autoridad de Carreteras, (USGS) United States Geological Survey, (OGP) Oficina de Gerencia y Presupuesto, (CRIM) Centro de Recaudos e Ingresos Municipales

Cartografía Elaborada por: División SIG, Oficina de Planificación Estratégica y Ordenación Territorial, Municipio Autónomo de Manatí

Anejo 7

Mapa sobre la Delimitación de la Cuenca del Río Grande de Manatí

Delimitación de Cuenca del Río Grande de Manatí



Leyenda

- Hidrografía de la Cuenca del Río Grande de Manatí
- Limite Municipal Manatia
- Mar, Lagos, Lagunas, Ríos y Quebradas
- Cuenca Río Grande de Manatí

MODELO DE DIGITAL DE ELEVACIÓN

Valores Producidos por Sombra

Máximo

Mínimo

1:282,000

Fuente de Información suministrada por: (DRNA) Departamento de Recursos Naturales, (JP) Junta de Planificación, (ACT) Autoridad de Carreteras, (USGS) United States Geological Survey, (OGP) Oficina de Gerencia y Presupuesto, (CRIM) Centro de Recaudos e Ingresos Municipales

Cartografía Elaborada por: División SIG, Oficina de Planificación Estratégica y Ordenación Territorial, Municipio Autónomo de Manatí

Delimitación de la Cuenca Ilustrada fue preparada por el DRNA

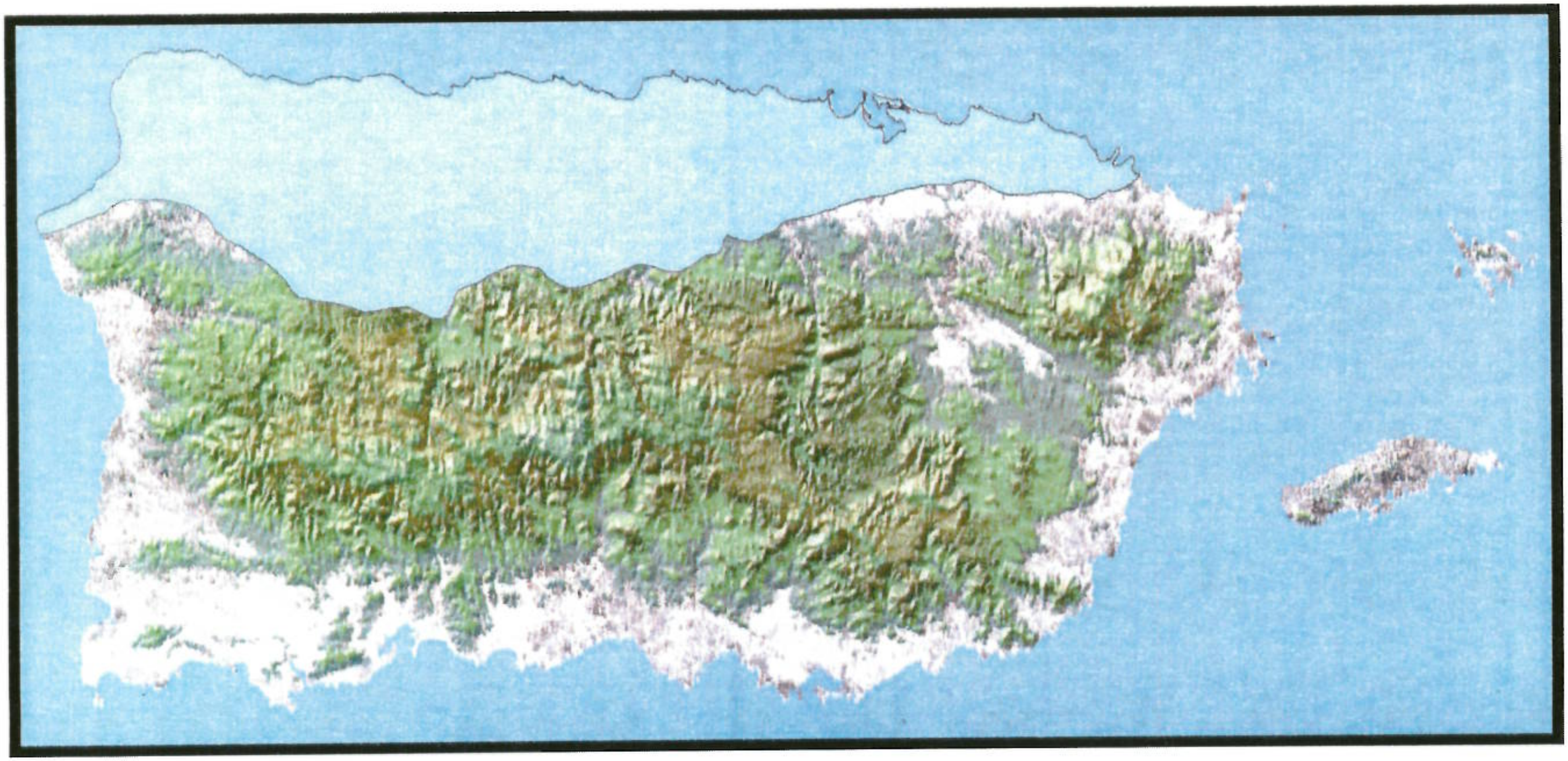
Anejo 8

Mapa Región del Karso para todo Puerto Rico.

Región General del Karso

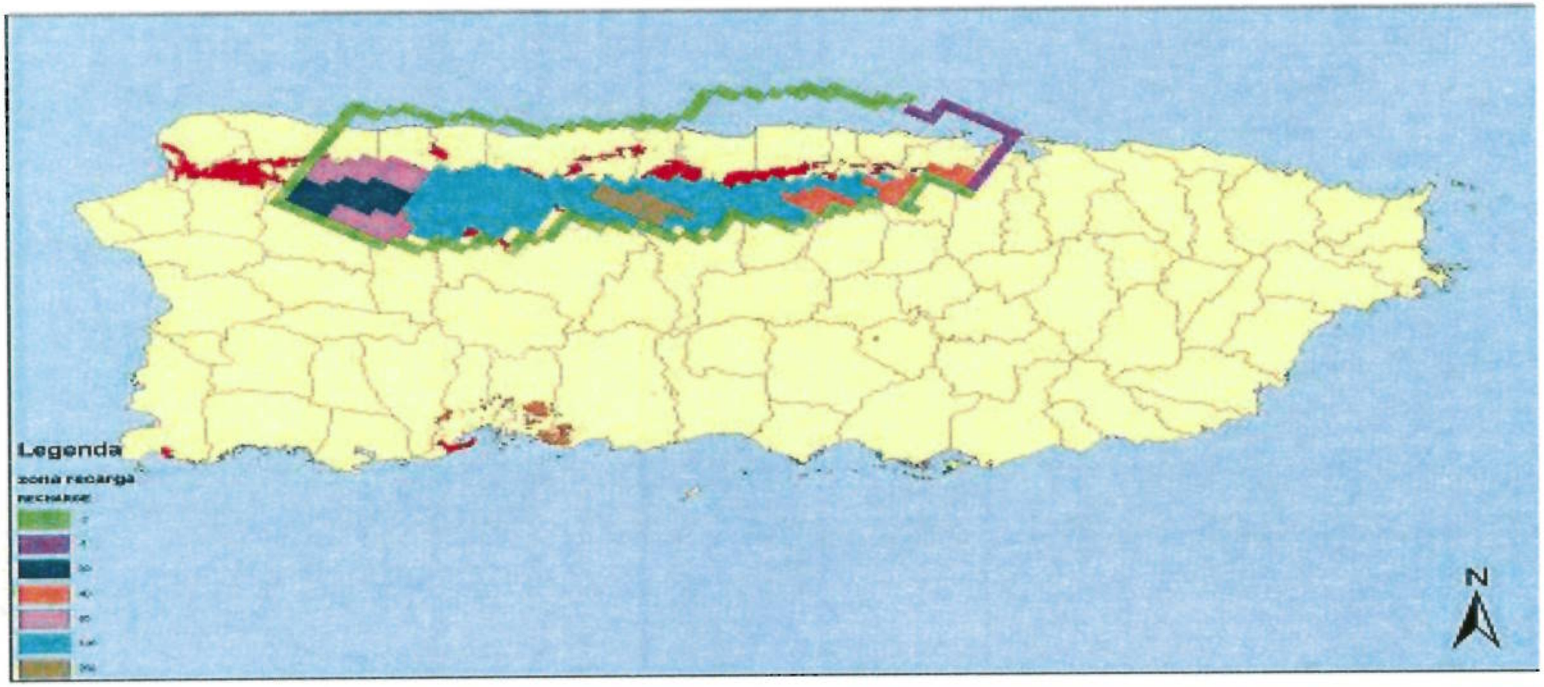
Fuente de información suministrada por: (DRNA) Departamento de Recursos Naturales, (JP) Junta de Planificación, (ACT) Autoridad de Carreteras, (USGS) United States Geological Survey, (OGP) Oficina de Gerencia y Presupuesto, (CRIM) Centro de Recaudos e Ingresos Municipales

Cartografía Elaborada por: División SIG, Oficina de Planificación Estratégica y Ordenación Territorial, Municipio Autónomo de Manatí



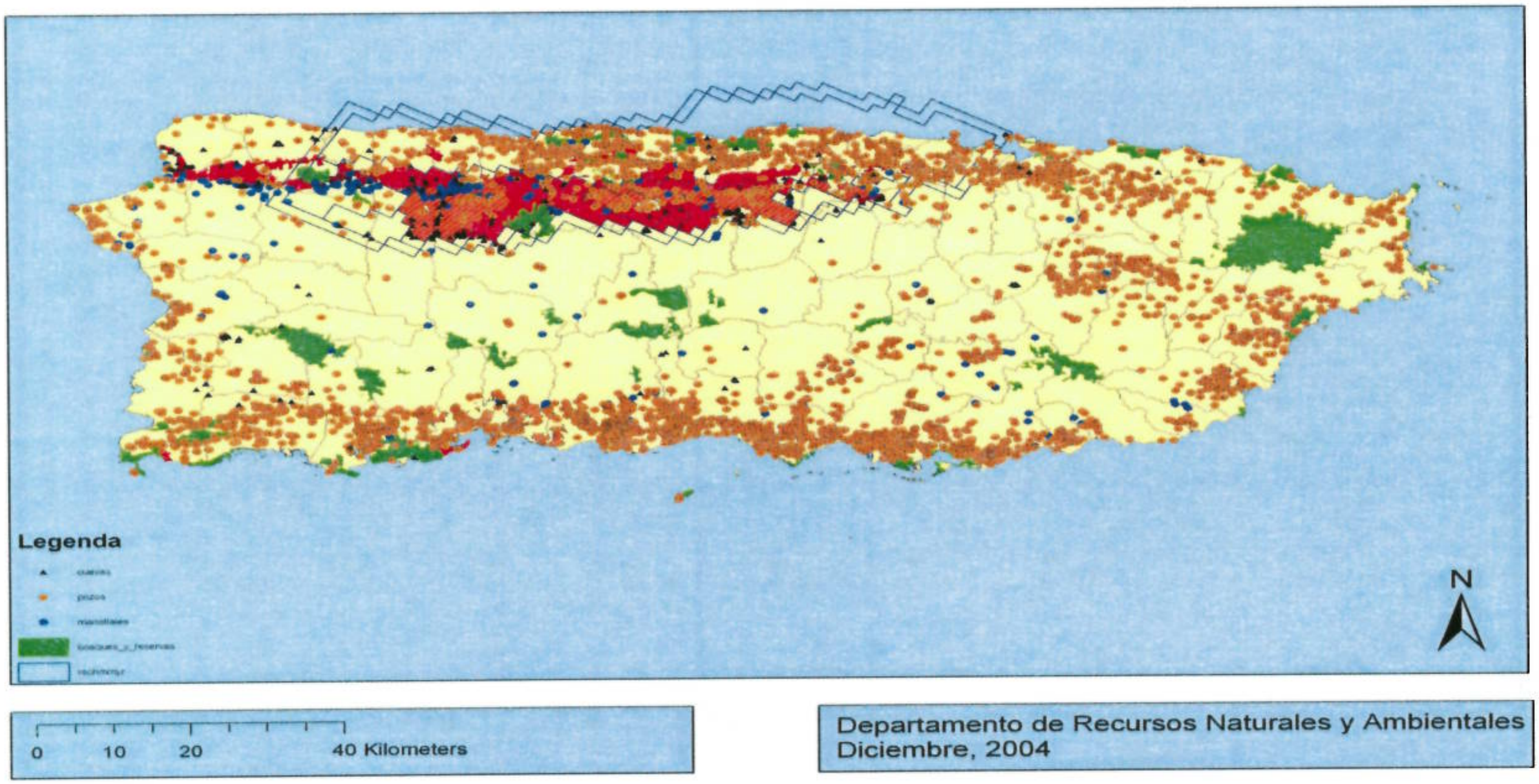
REGIÓN DEL KARSO

Terrenos del Carso con Prioridad de Conservacion



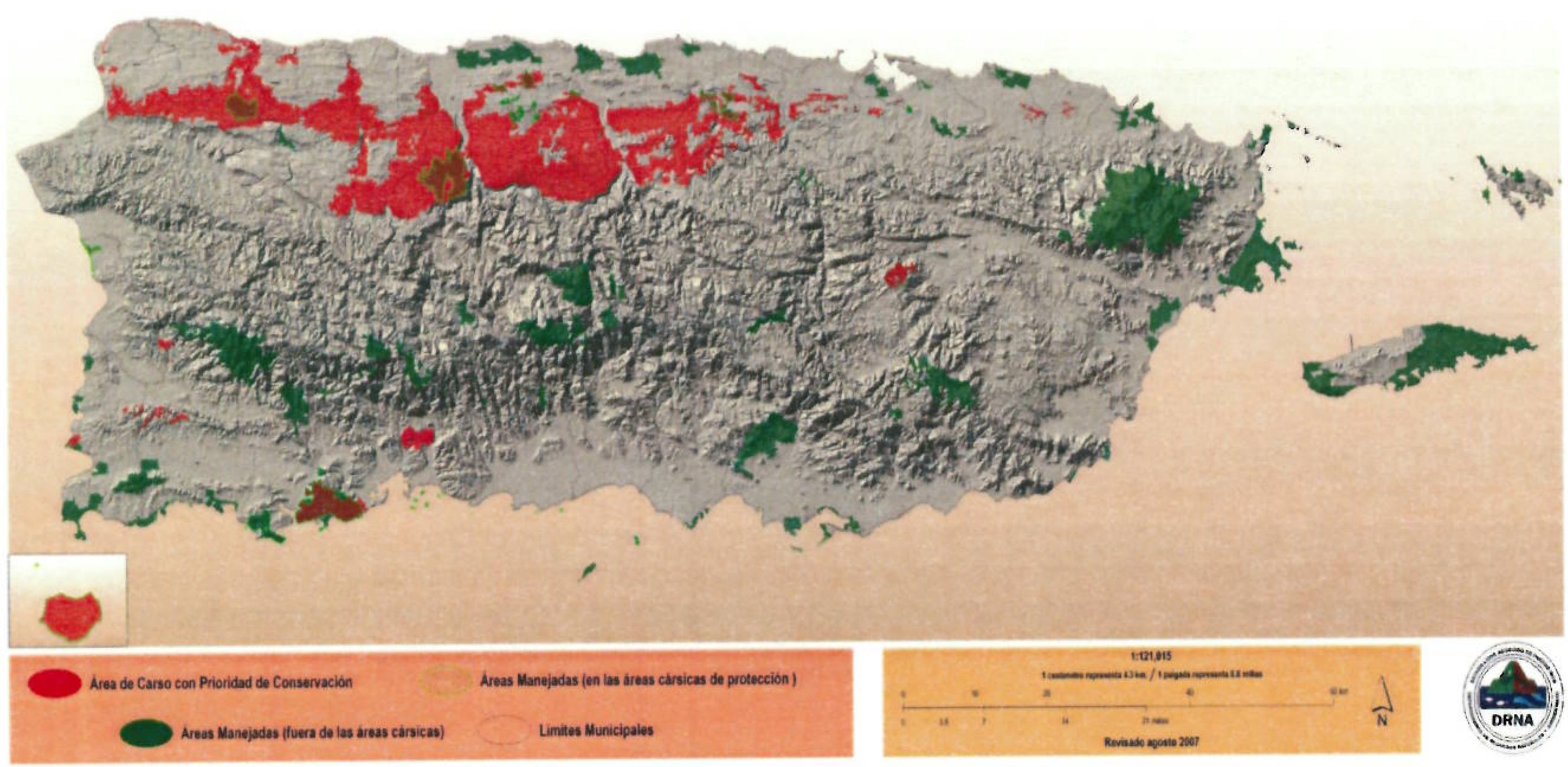
Departamento de Recursos Naturales y Ambientales
Diciembre, 2004

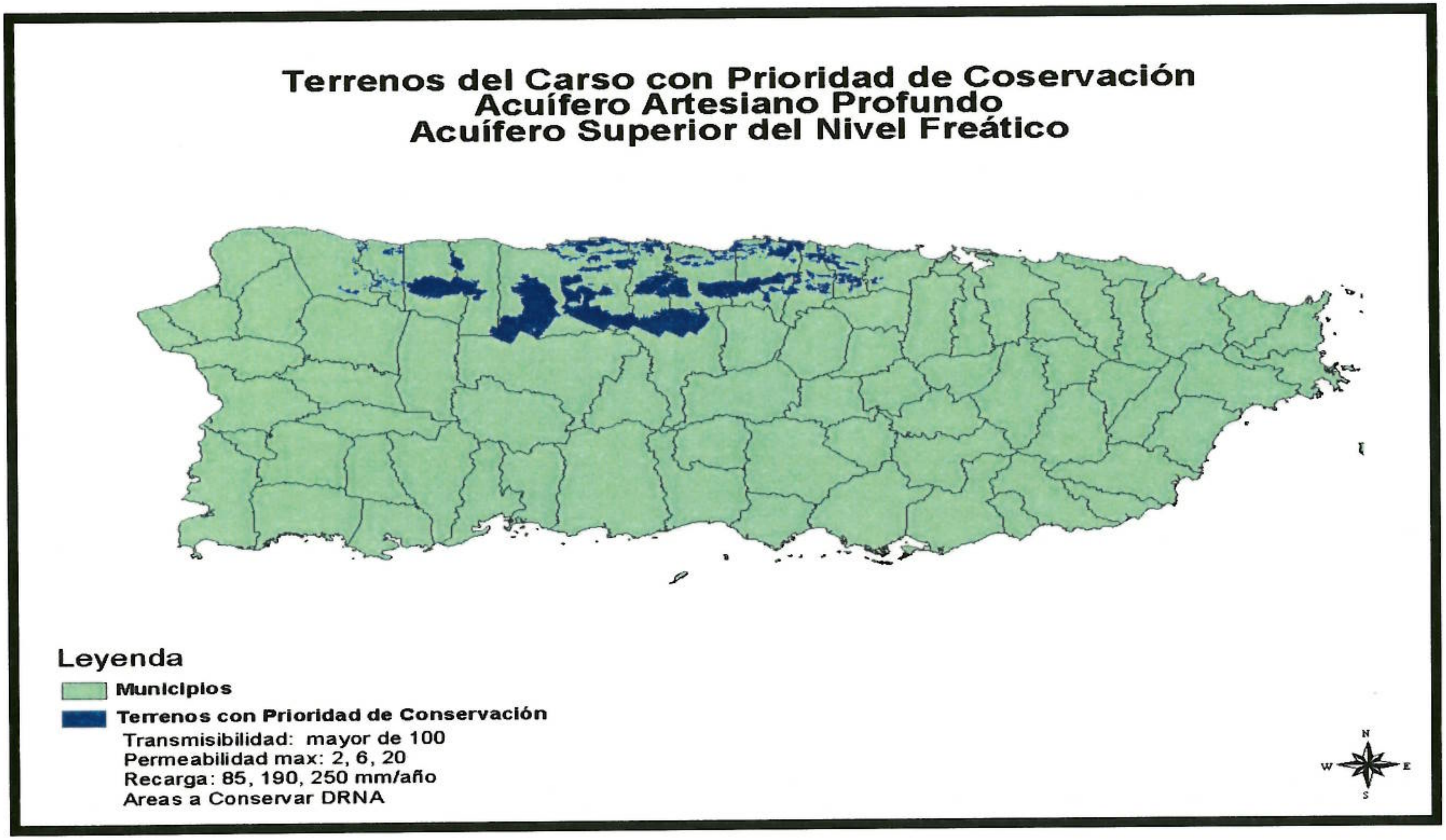
Terrenos del Carso con Prioridad de Conservacion



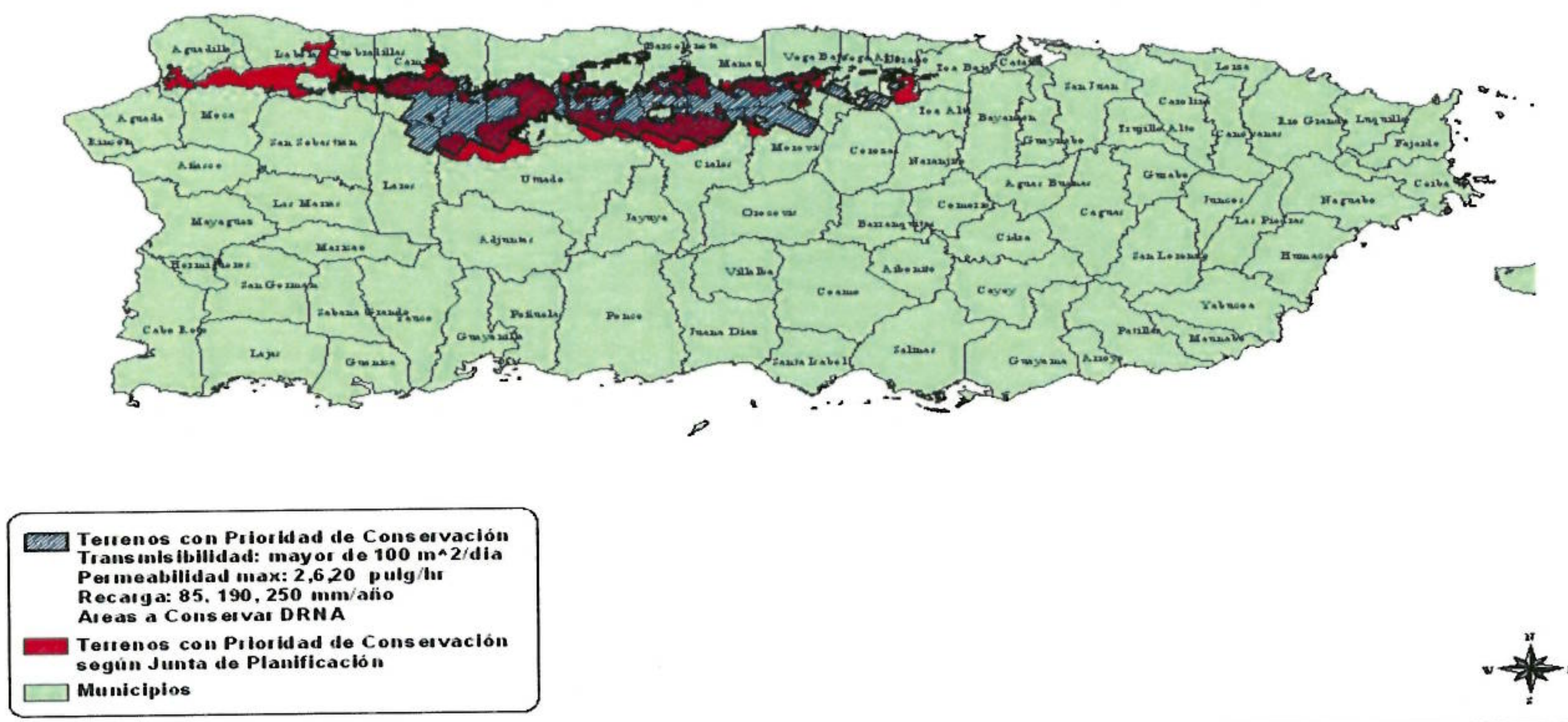
Mapa 1

Terrenos del Carso con Prioridad de Conservación




Terrenos del Carso con Prioridad de Coservación
Acuífero Artesiano Profundo
Acuífero Superior del Nivel Freático
Leyenda
Municipios
Terrenos con Prioridad de Conservación
Transmisibilidad: mayor de 100
Permeabilidad max: 2, 6, 20
Recarga: 85, 190, 250 mm/año
Areas a Conservar DRNA
N
W
E
S

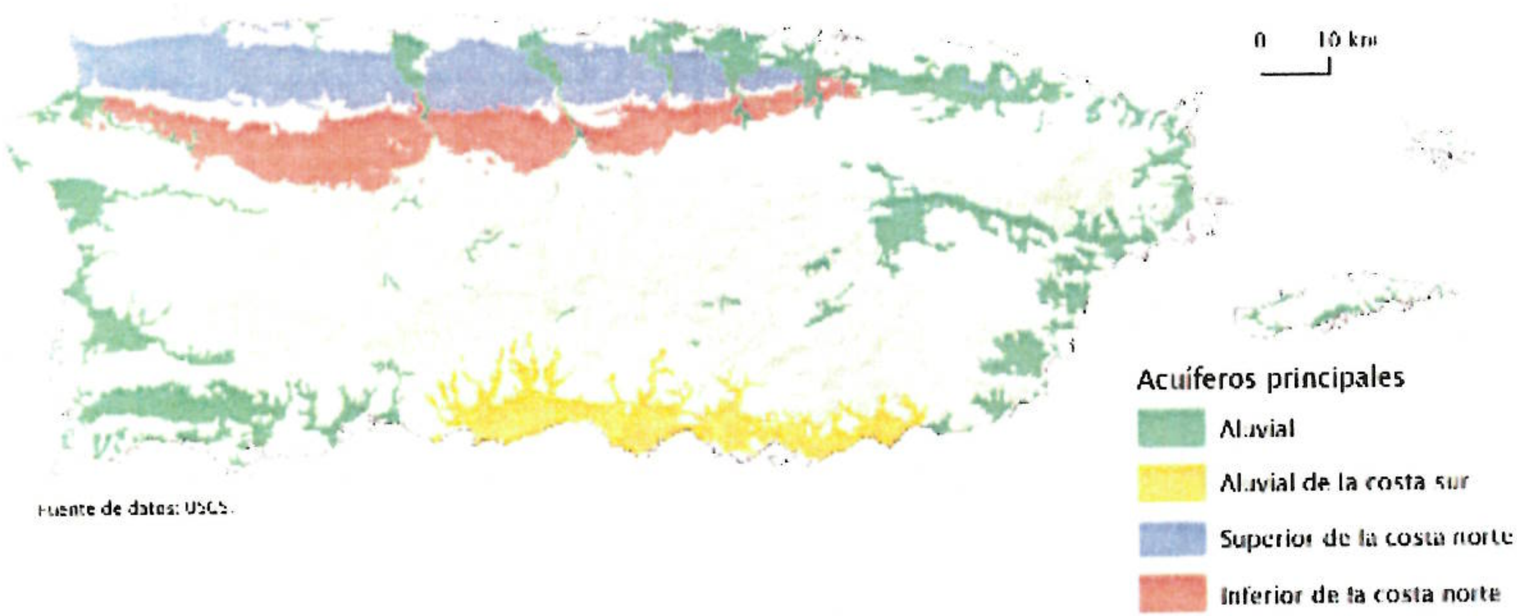
TERRENOS DEL CARSO CON PRIORIDAD DE CONSERVACIÓN
Acuífero Artesiano Profundo
Acuífero Superior del Nivel Freático



Anejo 9

Mapa de las Aguas Subterránea: Acuíferos Principales

Agua subterránea: acuíferos principales



Fuente de datos: USGS.

Conclusion

The protection of groundwater and surface water is indispensable for the security of our citizens. The Municipality of Manati depends almost entirely on groundwater in its territory to supply for domestic, industrial and agricultural use. The contamination[1] of this resource that is so vital for all constitutes a serious threat to health and public welfare; it is harmful to the flora and fauna, harms the environment, prevents or limits the legitimate benefits of water, devalues property and is offensive to the senses. We can not let this situation continue. That is why the protection of this resource should be a main priority and responsibility of our municipality.

Through this plan, we can conclude that the best way to deal with this problem is through prevention, supervision and monitoring activities that could pollute to a higher level our resources of water. This can be achieved by developing accurate and need measures to prevent contamination.

Maintaining the quality of our water is important for protecting our public health. If we protect our groundwater, we are ensuring the availability of our water resources for the enjoyment of future generations.

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